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Top and Root Development of Crested Wheatgrass (Agropyron Cristatum) and Intermediate Wheatgrass (A. Intermedium) During The First Season

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TOP AND ROOT DEVELOPMENT OF CRESTED WHEATGRASS (AGROPYRON CRISTATUM) AND INTERMEDIATE WHEATGRASS (A. INTERMEDIUM) DURING THE FIRST SEASON

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INTRODUCTION

Grassland research has undergone a definite acceleration since the great drought of 1933-40 (Albertson, 1949). The importance of grass in the conservation of our nation's agricultural resources has been brought clearly before research workers as well as the nation's population. In past years, especially after World War II, marginal and submarginal lands have been plowed and seeded to crops in an effort to supply food, and to take advantage of high crop prices (Albertson and Weaver, 1942).

Many acres of land, which have been proven unfit for cultivation, should be reseeded to suitable grasses and returned to grazing. This is a large task, as Pearse, et al. (1948) estimate that 80 million acres of land are depleted and must be reseeded if they are to recover and become productive in our generation. By 1948 approximately 5 million acres had been planted. Nixon (1949) states that in Oklahoma and Texas alone, about 7 million acres of depleted cropland should be returned to permanent grassland and 14 million acres of grazing land reseeded. The recent severe drought of the southwest will probably result in still larger acreages being put back to grass.

The re-establishment of grass on dusted or abandoned land by natural succession is a very slow process. In the western Great Plains, Shantz (1911) acquired data which indicate that 20 to 50 years is required to restore buffalo grass (Buchloe dactyloides) to its original state where the cover was destroyed by cultivation. At Hays, Kansas,

Riegel (1944) found that on a reseeded area blue grama (Bouteloua gracilis) attained a cover in 3 seasons exceeding the cover which had taken 24 years to develop on a natural revegetation site.

For satisfactory results in revegetation, a grass should be used which will rapidly cover the surface of the soil, provide abundant palatable forage for livestock, and be sufficiently hardy to withstand the variable climatic conditions of the Great Plains. Since damage to grassland may result from dusting and intense heat as well as from lack of precipitation it is necessary to plant a species which will endure these conditions (Weaver and Albertson, 1940).

RELATED STUDIES

Several studies have been made on both native and introduced grasses for reseeding purposes. Riegel (1940) studied variations in growth of blue grama grass from seed produced in various sections of the Great Plains. A similar study was conducted by Hopkins (1941) using side-oats grama grass (Bouteloua curtipendula). Life history and growth habits of buffalo grass were investigated by Webb (1940). Love and Hanson (1932) studied in detail the life history of crested wheatgrass (Agropyron cristatum) and compared its root development to that of bromegrass (Bromus sp.).

Many studies have also been made on the development and ecology of roots. Weaver (1919, 1920) did extensive research on roots of the grassland formation. He found that the depth of grass roots varies

from 2 to 10 feet, depending on the species and the nature of the habitat. Albertson (1937) observed that the majority of grass roots on the upland shortgrass sites near Hays, Kansas, terminated before reaching a depth of 5 feet. Hopkins (1953), also working in the mixed prairie, examined root development of 6 grasses on artificially revegetated land. Under nursery conditions Gibbens (1952) studied the root and top development of 5 native legumes and found they reached a depth of 7 feet or more in the first 20 weeks. Weaver and Darland (1949) determined soil-root relationships of some native grasses and their inter-relationships with the soil. Pavlychenko (1942), working on several forage crops, including crested wheatgrass, made a detailed analysis of the root systems of slender wheatgrass (Agropyron pauciflorum) and smooth brome (Bromus inermis). Many important studies have been made by other workers.

Many cool season grasses have been used for revegetating western ranges. Two species frequently used are crested wheatgrass and intermediate wheatgrass (Agropyron intermedium). The first season is the most critical in the establishment of grass on a reseeded area, and survival depends much on the production of a good root system. In Utah, Cook and Stoddart (1951) found that only about 3 percent of the viable seeds of 4 wheatgrasses became established and were alive at the end of the second year. Both crested and intermediate wheatgrass are adapted mainly to the Palouse grasslands and the northern and western portions of the Great Plains (Piper, 1925). Hafenrichter, et al.

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(1949) state that intermediate wheatgrass has about the same area of adaptation as smooth brome, but seems to be consistently better than smooth brome in hay production. It also produces an excellent root system. At the end of 4 seasons intermediate wheatgrass had produced 7,424 pounds of roots, while smooth brome produced only 3,221 pounds per acre to a depth of 8 inches. It was shown by Kirk, et al. (1934) that the roots of crested wheatgrass often penetrate to a depth of 8 feet in moist soil and may have a lateral spread of 2.5 feet. Pavlychenko (1937) calculated the total length of all roots of crested wheatgrass and found that they added up to 315.4 miles on a 3-year old plant.

METHODS OF STUDY

During the spring of 1954, seed of crested wheatgrass and intermediate wheatgrass was planted. No treatment or examination of the seed was made.

Selection and Preparation of Seedbed.

The study plot was on a clay loam floodplain occupied by puncture vine (Tribulus terrestris), Russian thistle (Salsola pestifer) and rough pigweed (Amaranthus retroflexus) which proved to be a constant source of trouble throughout the season. Prior to planting the plot was hoed deeply and raked 3 times to destroy as many weeds as possible.

Time and Method of Planting.

Seeds were planted April 1, 1954, in 3-row plots separated by

8 feet. The rows in each plot were 4 feet apart and 75 feet long. Shallow furrows were made with a hoe handle and seeds were covered with soil to a depth of approximately ¼ inch.

Care of Plants.

Plots were sprinkled every evening to hasten germination. After germination, water was sprinkled on the plot frequently until the roots became established. Thereafter, it was irrigated only when soil moisture became depleted.

A hoe was used to kill weeds between the rows, care being taken not to disturb the roots of the plants. In the row a dandelion digger was used to remove weeds and to thin the plants. At the beginning of the study individual plants were left in the row at 3-inch intervals. Later, plants were removed until a spacing of about 2 feet was obtained. This reduced competition to a point where it did not affect root development to any extent.

Method of Root Removal and Examination.

The root systems were removed from the soil by using a modified trench-tracing method (Weaver, 1919). All root systems of both wheatgrasses were removed intact, except the final specimen. Plants for examination were extracted about once a week until August 1. To get a representative specimen 5 plants were excavated each time and an average plant was chosen as an example. At the August 24 and December 1 digging, only 2 plants of each species were examined.

Measurements of Growth.

To determine the development of the plants, various parts of the extracted specimens were measured. These included (1) total length of leaves, (2) number of tillers, (3) air-dry weight of topgrowth at end of season, (4) number of main roots, (5) depth of root penetration and (6) total length of main roots. Results of these measurements should give a basis for comparison of these two grasses.

Since the leaves and stems of a plant are the parts utilized by livestock, and also contain the photosynthetic tissue, amount of leaves produced is an important aspect of the study. Total length of leaves was obtained by measuring each leaf and adding the results. Number of tillers was counted at the same times.

Air-dry weight of topgrowth was determined by clipping as closely as possible. Material air-dried, weighed and converted to pounds per acre.

Plants were removed from the soil and roots and tops were drawn to scale. Main root numbers were obtained by counting the roots arising from the root-stem transition zone. Depth of penetration was based on measurement of the root extending the greatest distance into the soil. Plants obtained were placed in a press and kept for future reference.

SOIL AND CLIMATIC CONDITIONS

Mechanical analysis of the soil was made by the hydrometer method developed by Bouyoucos (1936). Amount of clay in the top foot of soil as

compared to the next 4 feet was the greatest difference found in this determination. Percentage of sand, silt and clay in the 0 to 1-foot level was 16, 52 and 32 respectively. Soil from 1 foot to 5 feet was composed of an average of 7 percent sand, 53 percent silt and 43 percent clay. Small limestone rock fragments were sparsely interspersed throughout the upper 30 inches of soil, with a 1 to 2-inch layer tending to accumulate at the 2-foot depth.

The A horizon was dark-brown in color with a granular structure and good organic matter content. Structure became blocky and columnar at the 20-inch level, where it was yellow in color. Lime deposits became apparent at about two feet and continued to be visible to the bottom of the excavations, which were 7 feet deep.

General climatic conditions during the summer and fall of 1954 were very unfavorable for plant growth. It was hot throughout the season and especially in July when the average maximum temperature was 100 degrees F. and the average minimum was 69 degrees (Table I). During the period from June 1 to November 30, there were 88 days when the maximum temperature was 90 degrees or more, 37 days of 100 degrees or more, and 2 days when temperature exceeded 110 degrees.

In July maximum temperature was 100 degrees or more for 17 days, six of which were consecutive. August was not quite as hot as July, since temperatures of at least 100 were recorded for only 11 days and the maximum was 105 (Table I). Average maximum and minimum were 3 degrees lower in August than in July, showing a decrease in the extreme temperatures which result in desiccation of plant tissues.

Table I. Precipitation and temperature records for 1954 at Hays, Kansas.[1]

Month	Pptn. inches	Temp. max.	Temp. min.	Avg. temp. high	Avg. temp. low	Days exceeding 90°	Days exceeding 100°	Days exceeding 110°
June	2.65	104	38	89.6	61.4	18	5	0
July	1.06	111	62	100.0	69.0	29	17	2
August	2.66	105	55	94.9	66.3	22	11	0
September	1.98	104	40	89.6	59.1	19	4	0
October	1.93	96	20	68.8	42.1	3	0	0
November	T	78	8	62.0	28.5	0	0	0
Total	10.28					88	37	2

[1] Taken from Kansas climatological data.

Another climatic factor greatly affecting plant life was wind, which together with high temperatures increased transpiration. Evaporation was measured by loss from a free-water surface and was an indication of the rate of transpiration. The 6,103 miles of wind movement for June is 1.4 times that of the wind movement of 4,359 miles for July (Table II). The total evaporation for the period from June 1 to October 31 was 70.64 inches, or 3.06 times the average precipitation received in a year, and 6.9 times as much as the precipitation received during the summer months of 1954.

Growth of all plants in the plot was retarded by hail twice during the season. The first hailstorm came on August 1 and was very severe. Hailstones ranged up to 1 inch in diameter and for several weeks indentations could be seen in the surface of the soil. On October 11 another hailstorm gave the grass a rather severe beating. In general, growth conditions during the season were rather adverse.

RESULTS

Crested Wheatgrass

Emergence of the shoot above ground was first noted 7 days after planting and a seedling was removed the following day. The shoot was .95 inch long (Table III) and the root was 1.1 inches long (Table IV). Six days later the first leaf was 1.25 inches long and the root was 1.6 inches in length. Growth was rather slow, and two weeks after the first examination topgrowth had barely doubled in height to 2.1 inches,

Table II. Wind movement and evaporation from a free water surface at Hays, Kansas, during 1954.[1]

Month	Wind movement in miles	Evaporation in inches
June	6,103	16.52
July	4,359	18.78
August	4,518	14.03
September	4,819	14.95
October	4,367	6.36
Total	24,166	70.64

[1] Taken from Kansas climatological data.

Table III. Age in days, number of tillers, total length of leaves of crested wheatgrass.

Date	Age	Number	Total length (inches)
6-9	8	0	.95
6-15	14	0	1.25
6-23	22	0	3.2
7-3	32	1	7.1
7-14	43	2	8.2
7-22	51	2	8.5
8-1	61	3	21.1
8-24	84	5	51.0
12-1	183	106	325.0

Table IV. Age in days, number of main roots, depth of penetration and total length of main roots of crested wheatgrass.

Date	Age	Number	Depth (inches)	Length (inches)
6-9	8	1	1.1	1.1
6-15	14	1	1.6	1.6
6-23	22	3	1.9	2.7
7-3	32	4	4.0	7.4
7-14	43	5	5.0	14.7
7-22	51	6	5.5	14.9
8-1	61	7	7.0	16.0
8-24	84	11	14.0	43.0
12-1	183	65	38.0	2,165.0*

* Calculated

and the root had only increased .8 inch (Figure 1). On July 3, thirty-two days after planting, the plant had attained a height of 2.8 inches and the roots a depth of 4.0 inches. Eleven days later on July 14 leaves had been shriveled by hot winds and topgrowth was 2.0 inches high while the root extended into the soil 5.0 inches. Fifty-one days after planting topgrowth was still 2.0 inches tall while depth of root penetration was 5.5 inches. Ten days later, when plants were 61 days old, they were examined and found to be 4.0 inches tall and the roots had penetrated a maximum of 7.0 inches. On August 24, eighty-four days after planting, height of topgrowth was 6.0 inches while root depth was 14.0 inches. At the final digging on December 1 topgrowth had been frozen back to a height of 2.0 inches, however, the roots had attained a depth of 38.0 inches (Tables III and IV).

During the third week after planting new leaves and roots appeared with a resulting increase in the total length of leaves, number of main roots and total length of main roots (Figure 1). Total length of leaves corresponded to height of topgrowth until new leaves were formed. After appearance of new tillers and leaves total length of leaves greatly exceeded height of topgrowth.

A second leaf appeared 22 days after planting and total length of leaves was 3.2 inches. At this time 3 roots were present with a total length of 2.7 inches (Figure 1). The fourth examination on July 3 showed one new tiller with a resulting total leaf length of 7.1 inches. Root numbers had increased to 4 at this examination and total root

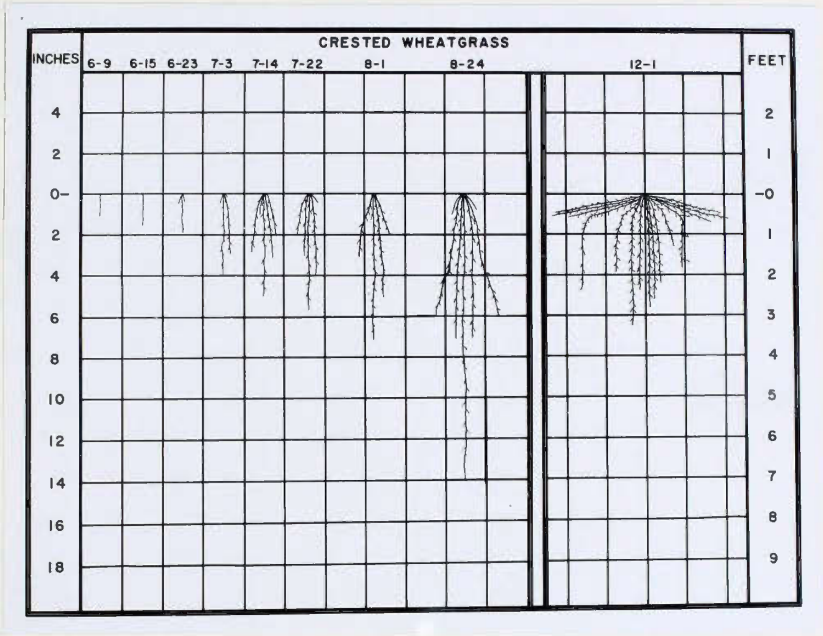

Figure 1. Root development of crested wheatgrass during the first season.

length to 7.4 inches (Table IV). Eleven days later another tiller appeared and the 5 leaves present had a total length of 8.2 inches. At this time another root had been produced for a total of five, and their total length was 14.7 inches.

On July 22, 51 days after planting, there were still only 2 tillers but the number of leaves had increased to 6. Total length of leaves at this time was 8.5 inches. One new root also appeared to make a total of 6 roots and their total length was 14.9 inches. Ten days later on August 1 only one new tiller had appeared, but secondary leaves had increased the total length of leaves to 21.1 inches. One more root was also added and total root length at this examination was 16.0 inches.

Plants of crested wheatgrass were not excavated again until August 24, which was 84 days after the planting date. Number of tillers had increased to 5 and total length of leaves was 51.0 inches. Increase for the preceding 23 days was 29.9 inches. At this time eleven main roots were counted with a total length of 43.0 inches.

At the final excavation on December 1 there were 106 tillers. They supported a total leaf length of 325 inches. The leaf blades were 3 to 5 millimeters wide and of varying lengths.

By actual count 65 main roots extended from the crown of the plant and calculated total length was 2,165.0 inches (Table I). Roots of plants excavated at end of study had a lateral spread of 4 to 4.5 feet. A scanty network of horizontal roots spread below the surface

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from 4 to 6 inches deep. They constituted about 25 percent of total number of roots and were 24 to 28 inches long. Remainder of roots had very few branches, grew almost straight down from the crown and most of them were less than 30 inches long. All roots of crested wheatgrass were very small in diameter.

Average yield from a single plant was 7.0 grams. Flower stalks were not produced.

Intermediate wheatgrass

Intermediate wheatgrass seedlings emerged at the same time as crested wheatgrass. The first excavation was made June 9 and the shoot was 1.3 inches, while the root was 1.5 inches long (Table V). An examination 6 days later showed the leaf to be 1.5 inches and root 2.1 inches long. At an age of 22 days two more leaves had appeared and height of topgrowth was 3.6 inches (Figure 2). Maximum depth of root penetration was 4.0 inches at this time.

On July 3, 32 days after planting, height of topgrowth was 1.5 inches. This reduction in height of topgrowth was due to the intrusion of rabbits in the study area and resulting removal of topgrowth. At this time depth of root penetration was 8.0 inches. Effects of topgrowth removal on roots was not apparent until later in the season.

Five days later, on July 8, topgrowth was 2.5 inches high. Roots had increased 1.0 inch to a maximum depth of 9.0 inches. At the next examination, July 14, plants were 43 days of age and height of

Table V. Age in days, number of tillers, total length of leaves of intermediate wheatgrass.

Date	Age	Number	Total length (inches)
6-9	8	0	1.3
6-15	14	0	1.5
6-23	22	0	9.7
7-3	32	2	9.8
7-8	37	2	19.1
7-14	43	2	11.1
7-22	51	2	10.0
8-24	84	5	43.2
12-1	183	116	405.0

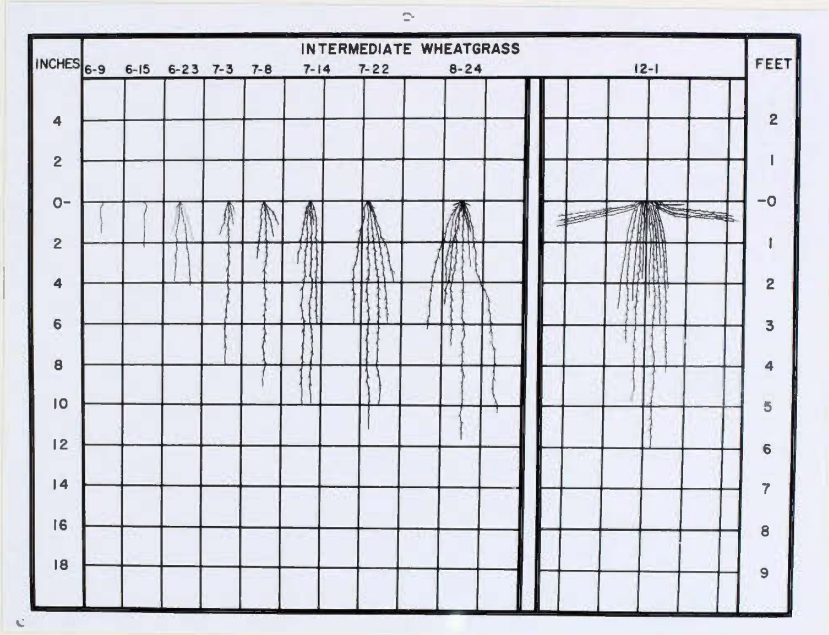

Figure 2. Root development of intermediate wheatgrass during the first season.

topgrowth was 4.5 inches, while depth of root penetration was 11.0 inches.

The next study was made August 24, 84 days after planting. Height of topgrowth was reduced slightly to 4.0 inches. However, depth of root penetration had increased to 11.5 inches. At the end of the study period on December 1, a tremendous increase in size of roots was quite apparent. While height of topgrowth had been reduced to 2.0 inches maximum root penetration was 72.0 inches.

Formation of new vegetative parts greatly increased total length of leaves and total length of roots. For the first and second examination total length of leaves paralleled height of topgrowth and total length of roots was equal to depth of penetration. At the third excavation total length of leaves was 9.7 inches while total length of the roots was 11.4 inches. There were no tillers present but a total of 3 roots were found.

On July 3, 10 days later, total length of leaves had increased only 0.1 inch to 9.8 inches even though 2 tillers were now present. Total length of the 4 main roots had increased 2.3 inches to a total of 16.7 inches (Tables V and VI). Five days later when plants were 37 days old the number of tillers remained at 2 but total length of leaves had increased to 19.1 inches. During this same period number of roots remained the same but total length had increased to 17.7 inches.

Forty-three days after planting, number of tillers had not increased and total length of leaves had been reduced to 11.1 inches

Table VI. Age in days, number of main roots, depth of penetration and total length of roots of intermediate wheatgrass.

Date	Age	Number	Depth (inches)	Length (inches)
6-9	8	1	1.5	1.5
6-15	14	1	2.1	2.1
6-23	22	3	4.0	11.4
7-3	32	4	8.0	16.7
7-8	37	4	9.0	17.7
7-14	43	5	10.0	23.0
7-22	51	5	11.0	37.0
8-24	84	14	11.5	43.5
12-1	183	121	72.0	5,114.0*

* Calculated

by rabbits. However, 1 new root was present and total length of roots had increased to 23.0 inches.

Data obtained at the July 22 excavation showed a small decrease in total length of leaves to 10.0 inches while number of tillers remained same. The next excavation was made August 24, 84 days after planting. During the previous 33 days number of tillers had increased to 5 and total leaf length measured 43.2 inches. For the same period number of main roots had increased to 14 and their total length was 43.5 inches.

At the final excavation on December 1, it was found that a tremendous increase in plant parts had occurred as 116 tillers were recorded. Total length of leaves at this time was 405.0 inches. Most of leaves were about 2 inches long and were 5 to 7 millimeters wide.

Number of main roots had increased to 121 and calculated total length was 5,114.0 inches. At the end of the season about one-third of the roots spread laterally 24 to 29 inches from the crown and reached a depth of only 4 to 5 inches. Remainder of the roots grew almost straight down from the crown. Eighty percent of these vertical roots were small (0.2 mm.) in diameter but the remainder were large, fleshy, white roots about .75 millimeters in diameter. The finer roots extended to a maximum of 73 inches with 75 percent of them terminating above 60 inches, but the large, fleshy roots were unbranched and reached a depth of only 20 to 28 inches.

Rhizomes did not appear until the final excavation. The one which was present was 8 inches long. Flower stalks and seed were never apparent throughout the season.

DISCUSSION

Data indicates that intermediate wheatgrass grew more rapidly than crested wheatgrass. Twenty-two days after planting, total length of leaves on intermediate wheatgrass was more than 3 times greater than crested wheatgrass. However, after the topgrowth of intermediate wheatgrass was removed by rabbits on July 11, difference in total length of leaves became less. During the period August 1 to 24 crested wheatgrass leaves exceeded intermediate wheatgrass in total length. Measurements at the final study show that intermediate wheatgrass had again surpassed crested wheatgrass in total length of leaves.

A comparison of root development of the two species would show that intermediate wheatgrass made a faster growth under the conditions that prevailed during the season. During the season roots of crested wheatgrass developed very slowly and at the end of the study period had attained a depth of only 38.0 inches with a total length of 2,165.0 inches. At the same time intermediate wheatgrass roots grew to a depth of 72.0 inches and had a total length of 5,114.0 inches. These figures illustrate the difference in rate of growth of the two species and the resulting development.

Rate of growth per day varied with age of the plants. Average rate was very low at the start of the season and increased as the number

of tillers and roots increased. For the first 22 days the average daily increase in total length of leaves of crested wheatgrass was 0.14 inch. For the last 99 days of the season the average daily increase was 2.77 inches. This shows the effects of increased number of tillers. Corresponding periods for intermediate wheatgrass shows that for the first 22 days the average daily increase was 0.44 inch and for the last 99 days it had been 3.66 inches per day.

Figures for increase in total length of roots show a similar difference. Average daily increase for crested wheatgrass during the season was 11.9 inches while intermediate wheatgrass averaged 28.0 inches per day. These figures should be attributed to the large increase in number of main roots.

The amount of forage per acre produced by the two species was calculated on the assumption of a plant density of 2 per square foot. The 7.0 grams of topgrowth clipped from crested wheatgrass would result in a calculated forage production of 1,344.0 pounds per acre. Intermediate wheatgrass produced 10.5 grams of topgrowth per plant and this would result in a calculated production of 2,016.0 pounds of forage per acre.

The data which have been presented would seem to indicate that intermediate wheatgrass might be preferred to crested wheatgrass for revegetating a site in this area. However, these results would not be conclusive because of the late planting date, optimum conditions of growth which were maintained and any errors which were made in choosing typical plants for study.

SUMMARY

This study was concerned with top and root development of crested wheatgrass (Agropyron cristatum) and intermediate wheatgrass (A. intermedium) during the first season of growth.

Seed was planted in deep alluvial soil June 1, and plants were weeded and watered when needed to maintain optimum conditions as nearly as possible. Thinning of plants was done to reduce competition and to ease the task of removing root samples. At the final excavation the plant spacing was approximately 2 feet. Roots and tops were examined about every 7 days for the first 51 days and at longer intervals until the final data was obtained December 1.

Measurements made to determine development were: (1) total length of leaves, (2) number of tillers, (3) air-dry weight of topgrowth at end of season, (4) number of main roots, (5) depth of root penetration and (6) total length of main roots.

In nearly all respects intermediate wheatgrass developed faster than crested wheatgrass. Only in total length of leaves between the 61st. and 84th. day did growth of crested wheatgrass exceed intermediate wheatgrass. At the end of the season total length of leaves of crested wheatgrass and intermediate wheatgrass was 325 and 405 inches, respectively. Number of tillers at the same time was 106 and 116 for the same plants. A crested wheatgrass plant yielded 7 grams while intermediate wheatgrass produced 10.5 grams of forage on December 1.

Crested wheatgrass had 65 main roots at end of the season with a total length of 2,165 inches and a maximum depth of 38 inches.

Intermediate wheatgrass had 121 main roots with a total length of 5,114 inches and a maximum depth of 72 inches. Roots of crested wheatgrass at the end of the study had a lateral spread of 4 to 4.5 feet. A scanty network of horizontal roots spread below the surface 4 to 6 inches deep. They constituted about 25 percent of the total number of roots and were 24 to 28 inches long. Remaining roots had very few branches, grew almost straight down from the crown and were mostly less than 30 inches long with some reaching 38 inches. All roots were very small in diameter.

At the end of season about one-third of the roots of intermediate wheatgrass spread laterally 24 to 29 inches from the crown and reached a depth of only 4 to 5 inches. The remainder of the roots grew almost straight down from the crown. Eighty percent of these vertical roots were small (0.2 mm.) in diameter but the remainder were large, fleshy, white roots about 0.75 mm. in diameter. The finer roots extended to a maximum of 73 inches with 75 percent terminating above 60 inches, but the large fleshy roots were unbranched and reached a depth of only 20 to 28 inches. A rhizome 8 inches long was present at the final examination. The two grasses did not produce seed.

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